Sustainable Mobility

An Approach to minimize Vehicular Pollution in India

Problem Statement :

The **annual car sales in India** are projected to increase from the **current 3.5 million to about 10.5 million** — a three times **increase — by 2030, which will increase exposure to vehicular exhaust emissions.**

- India is the **fifth-largest global car manufacturer** with one of the highest compound annual growth rates (10%) of vehicle registration as of 2019.

Key Points

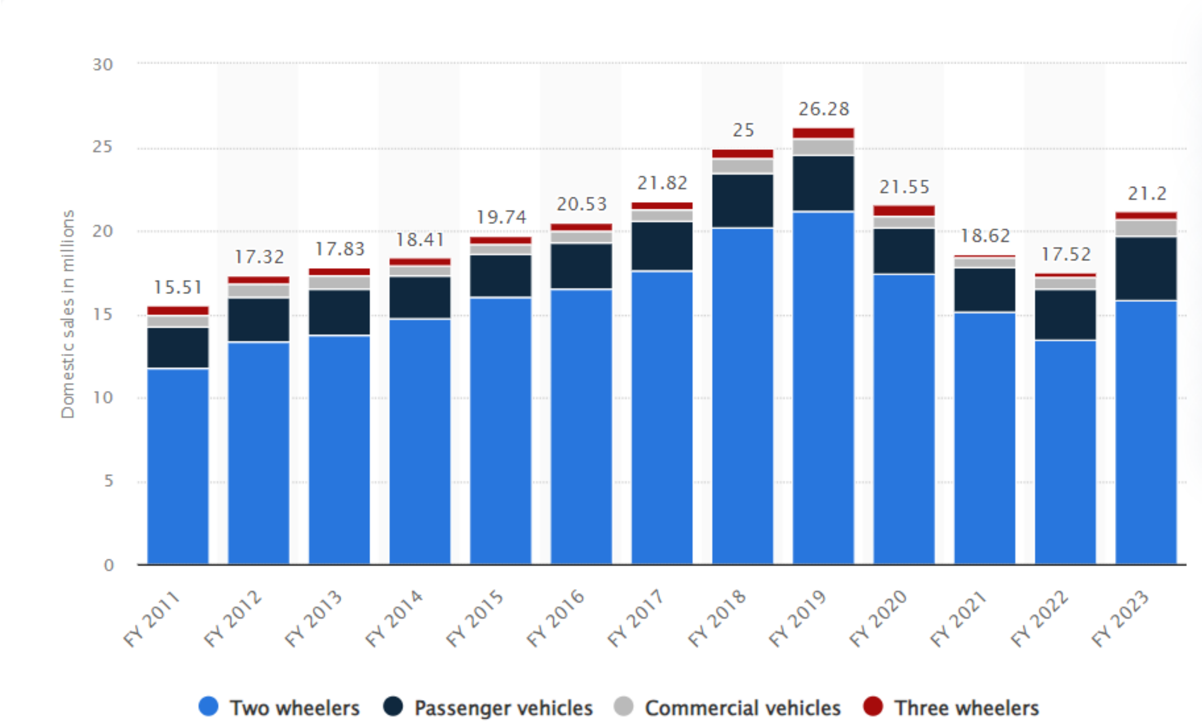
- **Vehicular Emissions in India:**
  - Vehicular emission is a **major cause of air pollution** in urban areas.
  - Typically, vehicular emission **contributes 20-30% of Particulate Matter (PM) 2.5** at the breathing level of air quality.
    - PM2.5 refers to particles that have a diameter less than 2.5 micrometres (more than 100 times thinner than a

human hair) and remain suspended for longer.

- According to studies, vehicles annually contribute about 290 gigagrams (Gg) of PM2.5.
- At the same time, around **8% of total Greenhouse Gas (GHG) Emissions** in India are from the transport sector, and in Delhi, it exceeds 30%.

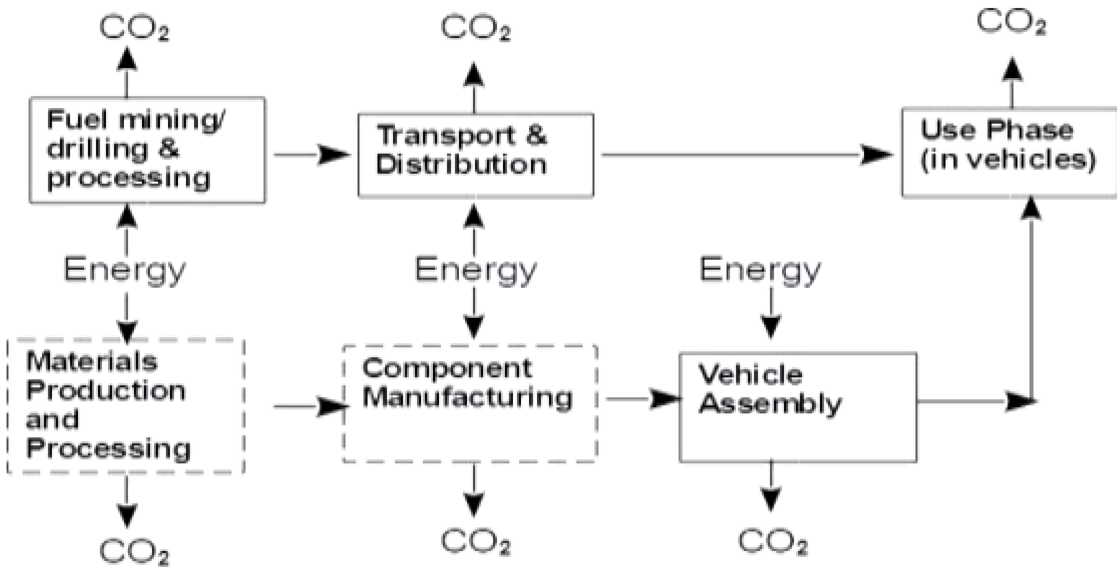
With increase in transportation needs , India would face three major challenges :

1) Crude oil imports
2) Regulate and decrease the GHC emissions.
3) Poor air quality due to GHC emissions.



Sales of automobiles in India from financial year 2011 to 2023, by type*(in millions)*

INVENTORY ANALYSIS:



IC Engine Vehicle: LCA Boundary

- The functional unit selected for this study is C-Segment passenger vehicle travelling a distance of 150,000 km in India.

For the following study we use a basic data ,

- Mid-size petrol
- Vehicle mass = 1240 kg
- Fuel =gasoline
- Fuel consumption = 6.667 l/ 100 km

The above data is BSIV standards we use for calculation of emissions for 150000 km travelled during the life time of the vehicle.

From that we get ,

- Carbon Monoxide (CO)-1gm/km (150kg)
- Hydro carbons (HC)-0.1gm/km (15kg)
- Nitrogen Oxides (NOx)-0.08 gm/km (12kg)
- Sulphur Dioxide (SO2)- 50 ppm (0.74kg)

Vehicle type	ICEV (Petrol)	ICEV (Diesel)	EV
Life time mileage (km)	150,000	150,000	150,000
Fuel economy	19 km/L [43]	24 km/L[43]	15kWh/100km
Weight (without battery) (kg)	932	1038	1285
Steel (%)	59.9	59.9	59
Cast iron (%)	1.9	1.9	0
Wrought aluminium (%)	4.6	4.6	3.1
Cast aluminium (%)	8.2	8.2	10.1
Copper/Brass (%)	2.4	2.4	5.9
Glass (%)	2.4	2.4	2.3
Plastic (%)	15.3	15.3	14.6
Rubber (%)	3.9	3.9	3.4
Others (%)	1.4	1.4	1.6
Battery type	Lead-acid	Lead-acid	Li-ion
Capacity (kWh)	/	/	40
Replacements during lifetime	2	2	0
Weight (battery) (kg)	20	20	186
Cathode active material (%)	/	/	30.8
Graphite/Carbon (%)	/	/	20.2
Binder (%)	/	/	1.8
Copper (%)	/	/	7.2
Wrought aluminium (%)	/	/	17.3
Electrolyte (%)	/	/	9.2
Lead (%)	69.0	69.0	/
Sulphuric acid (%)	7.9	7.9	/
Water (%)	14.1	14.1	/
Plastic (%)	6.1	6.1	/
Others (%)	2.9	9.1	13.5

The above data shows the percentage of raw materials need in manufacturing of Internal combustion vehicles .

Also the data provided below is for raw materials required for manufacturing the body of the car ;

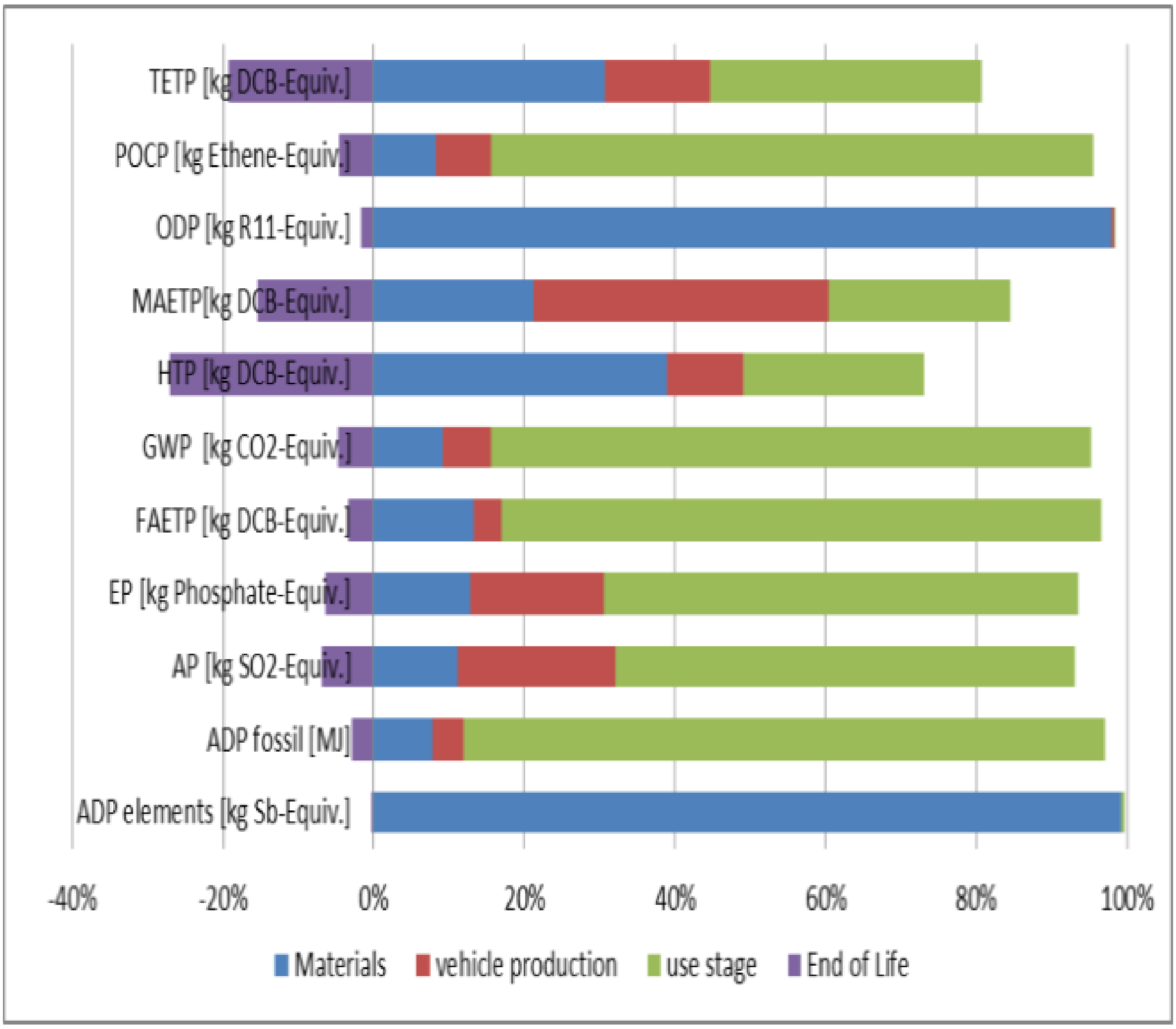
Material	% of Curb Weight	Weight (kg) for Steel Car	Energy Intensity Value MJ/Kg
Steel	54.2	560	60
Iron	10.1	104	37.3
Aluminium	6.4	66	231
Copper/ Brass	1.7	18	95
Lead	0.9	9	20
Rubber	6.8	70	88
Plastics	9.8	101	80
Glass	2.8	29	16
	92.7	958	

LCA Results : IC Engine Car (Gasoline)

Phase	IC Engine Car ($kgCO_2$)	BEV Car ($kgCO_2$)
Materials Production	3469	3370
Vehicle Manufacturing and Assembly	4070	2180
Battery Manufacturing	-	1548
Use Phase	58500	49440
Fuel Production, Delivery	13163	

IMPACT ASSESSMENT :

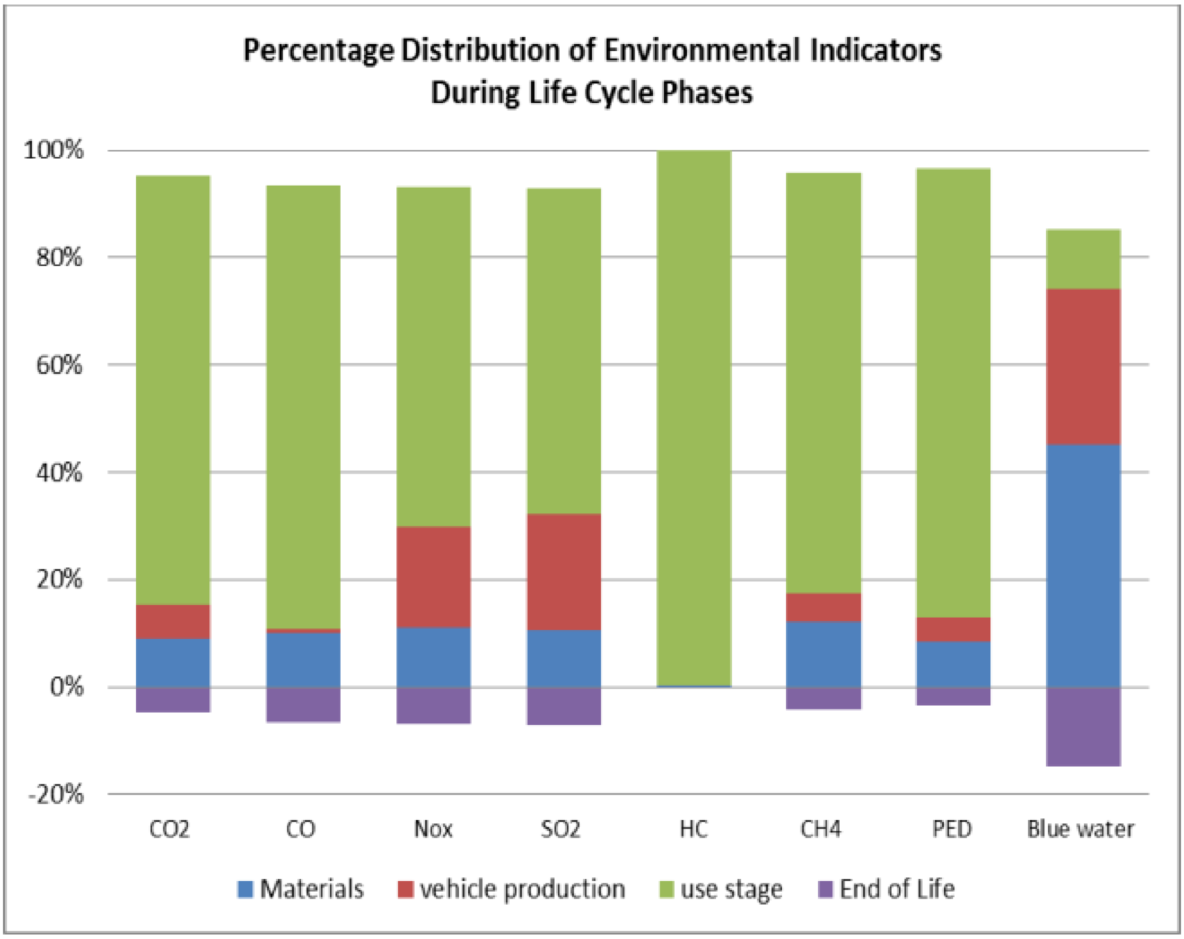
Graph 1 shows that the distribution of environmental impacts across various life cycle phases. The total product carbon footprint indicated by global warming potential is 35166 kg CO2e for the life cycle of the passenger car wherein 30982 kg is contributed by use stage and 3572 kg is due to material production.



GRAPH 1 : Percentage Distribution across life cycle stages

Life cycle impact results across the value chain

Indicators	Total	Material	Vehicle Production	Use	End of Life
Carbon dioxide (kg)	33665	3323	2373.9	29732	-1763.9
Carbon monoxide (kg)	172.7	20.2	1.5	164.2	-13.3
Nitrogen oxides (kg)	42.2	5.4	9.1	31	-3.3
Sulphur dioxide (kg)	68.4	8.4	17.2	48.3	-5.6
Hydrocarbons (unspecified) (kg)	15	0	0	15	0
Methane (kg)	60.6	8	3.4	51.9	-2.8
PED [MJ]	674453	61917	31764.9	604647	-23876
Blue water consumption [kg]	30413	19472	12622.2	4736.5	-6418.5



Carbon dioxide emission occurs largely during the use stage (88%) followed by material production (10%) and rest (7%) in the vehicle production stage with credit in the end of life stage (-5%). For carbon monoxide use stage contributes (95%) and materials production (12%).

Life cycle impact results for materials production

	ADP_non	ADP-Fossil	AP	EP	FAETP	GWP	HTP	MAETP	ODP	POCP	TETP
Magnesium	1.02E-06	155.51	0.06	0.00	0.13	17.78	4.68	3341.71	2.75E-11	0.006	0.107
ABS	6.93E-06	779.70	0.05	0.01	0.55	28.87	35.64	921.65	3.43E-08	0.010	0.054
Aluminium	0.000276	7159.05	2.39	0.16	3.87	653.15	2240.43	1078056.43	2.77E-07	0.157	1.061
Base coat	6.00E-05	3103.64	0.21	0.03	0.80	133.33	26.31	16843.08	6.48E-09	0.078	0.191
Carbon black	1.72E-06	130.56	0.01	0.00	0.05	4.87	0.19	221.05	5.15E-11	0.001	0.002
Ethylene glycol	1.00E-05	413.90	0.03	0.00	0.13	13.21	0.61	792.16	4.55E-10	0.015	0.008
Lead	0.02574	181.05	0.35	0.00	0.09	15.09	7.81	699.00	6.30E-10	0.029	0.057
Natural rubber	2.34E-06	45.66	0.08	0.03	0.49	-3.46	0.23	434.66	4.86E-11	0.004	0.002
Polyester	3.27E-05	2250.23	0.16	0.02	0.49	103.82	2.98	3148.68	1.60E-09	0.038	1.069
Polypropylene	6.36E-05	7626.05	0.36	0.04	2.23	197.17	8.39	8773.71	1.74E-08	0.085	0.079
Polyvinyl Chloride	2.69E-06	15.04	0.00	0.00	0.00	0.64	0.02	30.89	1.80E-10	0.000	0.000
water	1.58E-10	0.00	0.00	0.00	0.00	0.00	0.00	0.09	2.84E-15	0.000	0.000
polyurethane	0.000398	2744.69	0.18	0.04	0.55	132.47	3.32	5247.67	2.73E-09	0.042	0.130
Zinc	0.000373	2.97	0.00	0.00	0.00	0.25	0.05	34.04	6.29E-11	0.000	0.001
Float glass	0.000118	528.28	0.36	0.04	2.28	45.02	194.59	86926.09	3.72E-09	-0.040	0.238
Sulphur	8.38E-09	3.37	0.00	0.00	0.00	0.07	0.01	3.91	3.62E-12	0.000	0.000
Palladium	0.000148	43.33	0.06	0.00	0.10	3.67	3.14	622.20	9.31E-11	0.003	0.032
Platinum	0.002141	446.71	0.58	0.02	0.48	42.03	15.69	5270.60	1.34E-09	0.028	0.173
GLO: Rhodium mix ts	0.001011	196.65	0.25	0.01	0.15	18.96	5.08	2209.15	6.34E-10	0.012	0.059
Steel hot dip galvanized	0.02206	11432.33	3.35	0.21	2.76	1101.24	137.05	267892.84	1.35E-05	0.539	1.643
Steel billet / slab/ bloom	3.18E-05	6914.89	3.30	0.18	0.89	687.62	104.28	230750.68	3.83E-09	0.335	3.656
Copper	0.041082	742.90	0.67	0.03	1.64	66.61	41.56	47993.26	8.37E-10	0.034	0.387
Diesel	2.76E-07	348.84	0.03	0.00	0.06	4.14	0.74	1633.77	2.18E-11	0.004	0.007
Gasoline	9.12E-07	1167.54	0.14	0.01	0.24	17.56	3.66	4314.79	5.59E-11	0.016	0.032
Lubricants	4.09E-07	526.02	0.13	0.00	0.14	16.24	2.95	2466.95	2.92E-11	0.012	0.034

Lead and Copper are the major contributors for ADP (elements), whereas Polyester and Polypropylene are the moderate contributors. Similarly, in ADP- Fossil, Aluminum, Polypropylene and Steel hot dip galvanized are the major impactors followed by Copper and Lubricants. AP is mainly contributed by steel and paint followed by Lead. EP is primarily accounted by Aluminium and Steel while moderate impact was caused by ABS and Natural Rubber. GWP is mainly caused by Aluminum and Steel with medium impact due to magnesium and ABS. HTP is highly contributed by Aluminum with medium impact caused by Magnesium and ABS.

CONCLUSION:

The LCA study indicates that GWP is significantly contributed by use stage (88%) for total life cycle impacts. Use stage contributes predominantly to most of the environmental indicators in the range of 35-90%) except abiotic depletion (element) and Ozone depleting potential. Raw material contributes significantly in abiotic depletion (element) to the tune of 99.7% and human toxicity (84%). Acidification potential and eutrophication potential are moderately contributed by vehicle production stage i.e. 24% and 20% respectively. End of life credits result in significant benefits to human toxicity and terrestrial ecotoxicity by 58% and 31% respectively. While evaluating the inventory level key environmental indicators, carbon dioxide emission is mainly contributed by gasoline combustion during the use stage followed by 10% accounted from material production. Similarly for carbon monoxide, use stage contributes to 95% followed by 12% from material production. Nitrogen dioxides is mainly contributed by use stage which includes the tail pipe emission as per BS IV standard and also due to production of gasoline in refinery. Sulphur dioxide emission indicates that use stage contributes significantly but major impact of use stage caused at the production of gasoline at refinery. Hydrocarbon emission is predominantly caused by use stage. On the contrary the blue water consumption is significantly contributed by material production (64%) followed by vehicle production (42%).Though vehicle assembly production does not have major impact on the life cycle impacts in comparison to material production and use stage emission for most of the environmental indicators, but results indicates that contribution of electricity consumption to the total vehicle production impacts varied from 74% to 99% of all the indicators.

Solution:

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